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Biographical notices of mineralogists recently deceased. (Fourth series.) [1]

By L. J. Spencer, M.A., Sc.D., F.R.S.
Keeper of Minerals in the British Museum of Natural History.

[Communicated June 3, 1930.]

IN the following list of 40 lives, with a range in ages from 32 to 91 years, the average age is 68·2 years. Including previous lists, the average of 384 lives is 64·9 years.

Araujo Ferraz (Jorge Belmiro de) [1883–1926], Brazilian mineralogist, was born at Rio de Janeiro on August 30, 1883, the son of Baron de Araujo Ferraz, and died there on February 7, 1926. He studied at the polytechnic school of his native city, taking the degree of doctor in civil engineering. After teaching physics and chemistry in the municipal school at Rio de Janeiro and in the School of Mines at Ouro Preto, he was appointed petrographer on the Geological and Mineralogical Survey of Brazil, of which for a time he acted as director. Dr. Araujo Ferraz had an extensive private collection, and he was responsible for the display of Brazilian minerals at the Torino exhibition in 1911 and at the Brazilian centenary exhibition in 1922. He translated and edited E. Hussak's work, 'Os satellites do diamante' [Min. Mag. **18**–148], and for many years had worked on a mineralogy of Brazil, portions of which have been edited by A. Roccati [Min. Abstr. **3**–446]. The mineral ferrazite, named after him, is one of the 'favas' from the Brazilian

[1] Series I–III in Min. Mag., 1921, vol. 19, pp. 240–259; 1924, vol. 20, pp. 252–275; 1927, vol. 21, pp. 229–257. An index to earlier notices in vols. 1–19 was given in vol. 19, pp. 259–262.

diamond deposits. He was a member of our Society since 1920. (A. Roccati, Bull. Soc. Franç. Min., 1926, vol. 49, pp. 145–148.)[1]

Artini (Ettore) [1866–1928], Professor of Mineralogy at Milano and Director of the Civic Museum of Natural History, was born at Milano on August 29, 1866, and died there on March 7, 1928. He studied in Firenze and Padova, and from 1887 to 1893 was assistant to Prof. F. Sansoni in the Mineralogical Institute of the University of Pavia. In 1893 he was placed in charge of the section of mineralogy in the Civic Museum of Natural History in Milano, of which Museum he became director in 1912. He was also teacher of mineralogy and of constructional materials in the Technical Institute and the Agricultural School, and later (1924) Professor of Mineralogy in the new University at Milano. Artini was the author of a number of descriptive papers on Italian minerals and rocks, and on the crystallography of organic compounds, especially derivatives of benzene. He described bavenite, bazzite, and brugnatellite as new species, and artinite was named after him by L. Brugnatelli in 1902. He also wrote several textbooks, one of which, 'I minerali' [Min. Abstr., vol. 1, p. 300], passed through three editions. He was president of the Italian Geological Society (1919 and 1925) and of the Italian Society of Natural Science (1904–1912). (Obituary notices by G. D'Achiardi, Boll. Ufficio Geol. Italia, 1929, vol. 54 (for 1928), no. 13, 16 pp., with portrait and bibliography of 104 items. E. Repossi, Atti R. Accad. Sci. Torino, 1928, vol. 63, pp. 190–192.)

Ettore Artini.

Braly (Adrien) [1864–1927], prospector, was born at Montbrison, Loire, on March 13, 1864, and died in Paris on August 6, 1927. The material collected on prospecting expeditions was worked out by him in the laboratory of the Natural History Museum at Paris, where he devised many new blowpipe methods for testing ore-minerals [Min. Abstr., vol. 3, p. 510]. (Obituary notice by A. Lacroix, Bull. Soc. Franç. Min., 1927, vol. 50, pp. 460–463, with bibliography.)

[1] Here the second name is given incorrectly as Palmiro, and the date of death as February 8.

Bravo (José J.) [1874–1927], Director of the Cuerpo de Ingenieros de Minas y Aguas de Peru, was born at Lima on April 17, 1874, and was killed in a motor-car accident at Akron, Ohio. He was also Professor of Physical Geography in the University of Lima and of Mineralogy and Geology in the Engineering School, and he was a leading spirit in scientific matters in Peru. From the vanadium deposit of Cerro de Pasco he described in 1906 the mineral rizopatronite (= patronite), and another mineral from the same locality was named bravoite by W. F. Hillebrand. (L. Garcia, Amer. Min., 1928, vol. 13, pp. 103–104.)

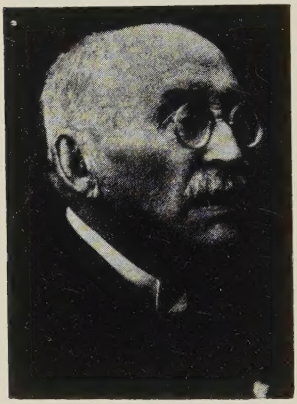
Brugnatelli (Luigi) [1859–1928], Professor of Mineralogy in the University of Pavia, was born at Sairano, near Pavia, on December 9, 1859, and died on April 27, 1928. His great-grandfather, grandfather, and father had been professors of chemistry at Pavia since 1796. After graduating in chemistry at Pavia in 1883, he spent some years at Torino and under Groth at München, returning to Pavia in 1888, where he was appointed full professor in 1904. His published papers, relatively few in number, and none since 1904, deal with Italian minerals and the crystallography of organic compounds. In 1894 he determined the crystallographic constants of potassium fluoborate, which has since been found as a mineral (avogadrite). Amongst the minerals described from the asbestos deposits in Val Malenco, Lombardia, was one he named artinite; and E. Artini returned the compliment by naming another closely allied mineral from the same deposits brugnatellite. (G. D'Achiardi, Rend. R. Accad. Lincei, Cl. Sci. fis. mat. nat. Roma, 1929, ser. 6, vol. 10, Comm. pp. xvii–xxv, with portrait and bibliography. A. Pelloux, Bull. Soc. Franç. Min., 1929, vol. 52, pp. 69–71.)[1]

Bruhns (Franz Siegfried Willy) [1864–1929], since 1909 Professor of Mineralogy and Petrography in the Mining Academy at Clausthal in the Harz, was born at Leipzig on February 5, 1864, and died on June 18, 1929. He graduated at Leipzig in 1886, and was afterwards assistant in mineralogy, first at Bonn (1889) and later (1894) at Strasbourg. At Strasbourg he also worked on the Geological Survey of Elsass-Lothringen. At Bonn he compiled an elaborate index of the works of G. vom Rath, and in 1906 he prepared a new

[1] In Bull. Soc. Franç. Min., 1928, vol. 51, p. 340, the date of death is given incorrectly as April 28, 1928; and in Poggendorff's 'Biographisch-literarisches Handwörterbuch', 1902, vol. 4, p. 193, the year of birth as 1860.

edition of von Dechen's ' Die nutzbaren Mineralien und Gebirgsarten im Deutschen Reiche '. W. Bruhns was also the author of elementary text-books on crystallography and petrography. With W. Busz in 1890 he described the mineral phosphosiderite.

Doelter (Cornelio August) [1850–1930], was born on September 16, 1850, at Arroyo, Porto Rico in the West Indies, where his father was a German planter and slave-owner, who had emigrated from Emmendingen in Baden. His mother, Francisca Cisterich, was Spanish, and on this account his name was sometimes given as Doelter y Cisterich. He died at Kolbnitz, Carinthia, on August 8, 1930. At the age of six he was taken to Paris, and he later studied at Freiburg in Baden, Heidelberg, and Wien, graduating (Ph.D.) at Heidelberg in 1872. For a time from 1873 he was attached to the Austrian Geological Survey, and in 1875 was a privat-docent in the University of Wien. From 1876 till 1906 he was Professor of Mineralogy in the University of Graz in Steiermark (= Styria), where in 1906 he was also Rector of the University. In 1907 he succeeded G. Tschermak as Professor of Mineralogy and Petrography in the University of Wien, from which post he retired with the title of Emeritus Professor in 1922.



C. Doelter (in 1930).

Doelter's earlier papers from 1873 dealt with volcanic rocks, during which period he produced monographs on the volcanoes of the Ponza Islands, the Cape Verde Islands, and of southern Tyrol. From 1884 he did intensive work on the synthesis of minerals and rocks and on silicate fusions. At a later period he was much interested in the changes in colour produced by the action of radium, X-rays, and other radiations on gem-stones and other minerals; and he wrote several papers on the cause of the blue coloration of rock-salt. Doelter wrote a number of books on chemical mineralogy, petrogenesis, precious stones, colour of minerals, and the mineral resources of the Balkans and Asia Minor; but his magnum opus, by which he will be best remembered, is his ' Handbuch der Mineral-

chemie '. This great work of reference (not entirely free from misprints) was commenced by him in 1911, after the age of sixty, and, although nine large volumes have appeared, it unfortunately remains incompleted at his death.

Draper (David) [1849–1929], a veteran South African geologist, was born at Capetown on January 3, 1849, his father being an early British settler in 1820. Only shortly before his death on September 9, 1929, he had taken part in excursions around Johannesburg of the International Geological Congress, pointing out the spot where gold was first mined on the Witwatersrand, explaining the geology and development of the Western Rand, and overflowing with interesting reminiscences amidst clouds of smoke from Boer tobacco. He had an adventurous and varied career. As a burgher he took part in the Basuto War of 1868, the defence against the Jameson Raid of 1895, and in the Boer War of 1899–1902. He went to Kimberley at the time of the first discovery of diamonds in 1868, and it was there that he first became interested in geology. His first papers on the geology of South Africa were contributed to the Geological Society of London in 1894 and 1895 ; but feeling that a local society was needed he was one of the founders and the first secretary of the Geological Society of South Africa, which was founded in Johannesburg in 1895. He spent several years in Brazil studying the diamond deposits ; and a white talcose matrix, called ' draperite ', was believed by him to represent a volcanic breccia allied to kimberlite. His last work was an interesting history, ' The birth of the diamond industry in South Africa ', the publication of which in parts in ' The South African Mining and Engineering Journal ' [Min. Abstr., vol. 4, p. 293] commenced only shortly before his death. The honorary degree of Doctor of Science was conferred on him by the University of the Witwatersrand in 1927. (Obituary notices in S. African Mining and Engin. Journal, 1929, vol. 40, p. 34, with portrait; Mining and Industrial Magazine of South Africa, 1929, vol. 9, p. 72; H. S. Harger, Trans. Geol. Soc. S. Africa, vol. 33 (for 1930), pp. 19–30, with bibliography and portrait.)

Giannotti (Carlo) [1897–1929], since 1922 assistant in the Mineralogical Institute in the University of Pisa, was killed in an aeroplane accident on October 16, 1929. He was born at Pieve Fosciana, Lucca, on December 21, 1897, and, after serving in the war as an observation officer in aeroplanes, he studied at Pisa and

Firenze. His few papers have recently been noticed in 'Mineralogical Abstracts', vol. 4, pp. 55, 82, 153, 299. (G. D'Achiardi, Atti (Proc. Verb.) Soc. Toscana Sci. Nat., 1929, vol. 38, preprint 4 pp.)

Glinka (Konstantin Dmitrievich), Глинка (Константин Дмитриевич) [1867–1927], Russian pedologist, was born at Smolensk, and died at Leningrad on November 2, 1927. After studying at St. Peterburg and Moskva, he became in 1894 assistant, in 1895 assistant professor in mineralogy and geology, in 1900 also professor of pedology, and later director of the Agricultural Institute at Nova-Alexandria, govt. Lublin (now Puławy in Poland). In 1913 and 1922 he was director of the Agricultural Institute in Voronezh and Leningrad respectively. In connexion with his work on the mineralogy of soils he studied the alteration of minerals and the weathering of rocks. Hydrothomsonite [Min. Mag., **15**–422] was described as a zeolite occurring in soils. (Obituary notices by V. V. Polynov, Priroda [= Nature], Leningrad, 1927, no. 12, pp. 935–942, with portrait; Sir E. J. Russell, Nature, London, 1927, vol. 120, pp. 887–888.)

Graves (John) [1842–1928], mineral dealer of Frizington, Cumberland, was born on March 12, 1842, at Langdale in the Lake District, and he died at an advanced age on December 3, 1928, at Frizington. When a young man he went to work as a miner in the west Cumberland iron mines, at a time when beautiful crystallized specimens of calcite and barytes were found in almost superfluous abundance. Seizing the opportunity, he collected these in large quantities and supplied dealers and museums all over the world. He thus did good work in preserving material which would otherwise have been largely destroyed and lost. At the time of the writer's first visit to Frizington in 1886 Graves had a large stock of minerals and a flourishing business.

Groth (Paul Heinrich *Ritter von*) [1843–1927], a well-known teacher and leader in mineralogy and crystallography, was born at Magdeburg in Preussen on June 23, 1843, but his childhood was spent at Dresden in Sachsen, where his father was a portrait painter. He died at München in Bayern on December 2, 1927, at the ripe age of 84. After studying at the Polytechnic School at Dresden, he passed in 1862 to the Mining Academy at Freiberg in Sachsen, where he was a pupil of Breithaupt. In 1865 he migrated to the University of Berlin, studying physics and crystallography under Gustav Rose,

and he graduated from there in 1868. During 1868–70 he was assistant in physics at Berlin, and during 1870–1872 teacher of mineralogy and geology in the Mining Academy at Freiberg. In 1872 he was appointed Professor of Mineralogy in the reorganized University at Strasbourg in Alsace, and in 1883 he was transferred to München as successor to F. von Kobell. The latter post, which included also the charge of the State Collection of Minerals attached to the University, he held till 1924, retiring at the age of 81. Both in Strasbourg and in München his laboratory was for many years the centre of training for mineralogists from all parts of the world. He was an inspiring teacher, and holding a unique position as a leader he did more than any one else in co-ordinating and stabilizing crystallographic nomenclature and methods.

P. Groth (in 1893).[1]

Groth's list of original scientific papers is a comparatively short one, the reason for this being that he always handed over a problem to his many advanced students, and in the publication of the results his name never appeared as joint-author, although he had actually directed the work. His first mineralogical paper, in 1866, was on an altered sphene from the syenite of Plauen near Dresden, to which J. D. Dana in 1867 applied the name grothite.[2] His doctor's dissertation in 1868 was on the isomorphism of the perchlorates and permanganates. Between that time and 1872 he published several papers on the relation between chemical composition and crystalline form, for example, amongst the derivatives of benzene, and it was then that he conceived the idea

[1] The above portrait showing Groth in his prime is reproduced from a photograph purchased by the writer in München in 1893, when a student under Groth. In those days photographs of professors were almost as popular as those of actresses, and both sorts were displayed together in many of the shop-windows.

[2] Grothine, of F. Zambonini, 1913, is another ill-defined mineral named after Groth. Distinguished mineralogists have been rather unfortunate in the minerals that have been named after them; and also, it may be said, they have often erred with the minerals that they have themselves described as new.

of morphotrophy. Chemical crystallography was the key-note of al his later work.

In other directions Groth did good and useful work in publishing standard text-books and works of reference. His 'Tabellarische Übersicht der einfachen Mineralien' (1874) and his 'Physikalische Krystallographie' (1876) each passed through four editions, with translations in other languages, and his monumental work 'Chemische Krystallographie' (5 vols., 1906–1919) brought together all the known crystallographic data relating to 7,350 substances. Other books deal with gem-stones, the Strasbourg and München mineral collections, 'Einleitung in die chemische Krystallographie' (1904), and lastly in 1926 an interesting history 'Entwicklungsgeschichte der mineralogischen Wissenschaften' [Min. Abstr., **3**–223] which he was particularly fitted to write. In 1877 he founded the 'Zeitschrift für Krystallographie und Mineralogie', which he edited until 1920 (vols. 1–55). In this work he obtained the willing co-operation of workers in all countries, and an excellent abstract review of the current literature was followed by detailed indexes which much simplified bibliographical search. This periodical, commonly known as 'Groth's Zeitschrift', has been carried on since 1921 by P. Niggli under the title 'Zeitschrift für Kristallographie', and in marking its jubilee Groth gave in vol. 66, only shortly before his death, an interesting review of the work that had been done [Min. Abstr., **3**–467].

The honours bestowed on Groth were not undeserved, for his name will for ever stand out as a landmark in the history of crystallography. He was knighted in 1903, but he always preferred to style himself P. Groth. He was an honorary member of our Society for over fifty years (elected March, 1877), a foreign member of the Royal Society of London since 1911, and an honorary life fellow of the Mineralogical Society of America (1926). He was elected a foreign correspondent of the Geological Society of London in 1895, a foreign member in 1900, and in 1908 received its highest award, the Wollaston Medal. The honorary degree of Sc.D. was conferred on him at Cambridge in 1904, and he was also honorary Ph.D. of Genève and Praha. In 1904 his portrait, painted by Prof. E. Grützner, was presented to him on behalf of 273 individual admirers [Min. Mag., **14**–66].

A 'Festband P. H. v. Groth' (= Zeits. Krist., vol. 58) was published in 1923 on the occasion of his eightieth birthday; this

contains a short biographical note, a portrait, and a bibliography of 69 titles of his published works for the period 1866–1921. (Obituary notices by Sir H. A. Miers, Nature, London, 1928, vol. 121, pp. 98, 107; Proc. Roy. Soc. London, Ser. A, 1928, vol. 119, pp. xx–xxii, with portrait. E. H. Kraus, Science, New York, 1928, vol. 67, pp. 150–152; Amer. Min., 1928, vol. 13, pp. 93–96, with portrait. H. Steinmetz, Ber. Deutsch. Chem. Gesell., 1928, vol. 61, Abt. A, pp. 65–68, with portrait. B. Mauritz, Földtani Közlöny, Budapest, 1929, vol. 58 (for 1928), pp. 29, 162–163.)

Henson (Samuel) [1848–1930], mineral and gem dealer, was born in London on September 22, 1848, and died at Chislehurst, Kent, on June 9, 1930. His father, Robert Henson,[1] had established a mineral business in 1840, and this was carried on by the son, first in the Strand and later in Regent Street, London. Since 1878 he had supplied a constant stream of carefully selected specimens for the British Museum collection of minerals. He had been a member of our Society for over fifty years (elected 1879), and in 1883 he contributed to the Magazine a short note on a fine crystal of apatite (now in the British Museum). His wife, Fanny Henson, also had a good knowledge of minerals and assisted in the business, and was also for some years, 1910–17, a member of our Society. She died in 1926.

Hiortdahl (Thorstein Hallager) [1839–1925], since 1872 Professor of Chemistry in the University of Kristiania (now Oslo), was born at Bergen on May 4, 1839, and died on October 29, 1925. He had studied in Paris under H. Sainte-Claire Deville and A. Des Cloizeaux, and at one time was assistant under T. Kjerulf in the mineral collection at Kristiania. He analysed several minerals and also the Tysnes meteorite, and determined the crystalline forms of homologous series of organic compounds. For several years he was one of the editors of the Norwegian journal 'Nyt Magazin for Naturvidenskaberne'. The mineral hiortdahlite was named after him by W. C. Brøgger in 1889. (V. M. Goldschmidt, Vid. Akad. Årbok, Oslo, 1926, pp. 65–69.)

Hirschwald (Julius) [1845–1928], since 1879 Professor of Mineralogy in the Technical High School, Charlottenburg, Berlin, was born on February 14, 1845, at Lauenburg in Pommern, and died on April 14, 1928, while on his return from a holiday cruise to

[1] Robert Henson [1814–1864] started as an assistant to James Tennant [1808–1881].

Tenerife. He studied at Danzig, Berlin, and Zürich, and graduated at Tübingen in 1868 with a crystallographic dissertation. He joined the old Trade School (Gewerbeakademie) in Berlin which by amalgamation with the School of Architecture (Bauakademie) formed the Charlottenburg Institute in 1879, of which he was the first professor of mineralogy and geology, then attached to the division of chemistry and metallurgy. There he built up a good mineral collection, the most important acquisition being the collection of Friedrich Tamnau (1802–1879). Later, he devoted much attention to the study of building stones, starting a collection and a laboratory for testing the materials, and on this subject he wrote several reports and text-books. On his retirement in 1926, this was divided up and the mineralogy and geology was amalgamated with the mineralogy and petrography of the Mining Academy to form a new Institute for Mineralogy and Petrography. (K. H. Scheumann, Centralblatt Min., Abt. A, 1928, pp. 242–252, with bibliography.)

Kišpatić (Mišo = Mijo = Mijat = Mihály = Michael)[1] [1851–1926], since 1894 director of the mineralogical and petrographical section of the Croatian National Museum at Zagreb (= Agram) in Yugoslavia. He was also from 1896 to 1918 Professor of Mineralogy and Petrography in the University of Zagreb, in which post he was succeeded by Fran Tućan. He was born at Osijek (= Eszék = Esseg) in Slavonia on September 21, 1851, and died at Zagreb on May 17, 1926. He wrote several papers on the rocks and minerals of Croatia and Bosnia, and did much to popularize the study of natural sciences in Yugoslavia. In a detailed study of the bauxite deposits of the Croatian Karst region he proposed the name sporogelite for a constituent of the bauxite. (Obituary notice in Priroda, popularni časopis hrv. prirodoslovnog društva u Zagrebu, 1926, vol. 16, pp. 129–130, with portrait.)

Kitto (Benedict) [1841–1928], a well-known assayer, was one of the founders and an original member of council of this Society in 1876. He was also a founder and trustee of the Institution of Mining and Metallurgy in 1892, and a fellow of the Geological Society since 1873. He was born at Breage in Cornwall on February 9, 1841, and died in London on May 13, 1928, at the

[1] The various equivalent forms were used following the language (Croatian, Serbian, Slovene, Hungarian, or German) in which his published papers were written.

advanced age of 87. He attended classes at the old College of Chemistry and at the Royal School of Mines in London, and for some years (1872–1880) was lecturer and assistant secretary to the Cornwall and Devon Miners' Association. In 1881–1882 and 1892–1928 he was public analyst for the county of Cornwall, and from 1882 to 1887 chief chemist and assayer in London to the Rio Tinto Mining Company. In 1887 he established a practice in London as assayer, analyst, and consulting chemist and mineralogist, which is still carried on as Benedict Kitto & Sons.

Koch (Antal = Anton, *of Bodrog*) [1843–1927], Hungarian geologist, was born at Zombor, Hungary (now Sombor in Yugoslavia) on January 7, 1843, and died on February 8, 1927. He studied in the University of Budapest, where he was later assistant to J. Szabó. He joined the Hungarian Geological Survey in 1869, and in 1872 was appointed Professor of Mineralogy, Geology, and Palaeontology in the University of Kolozsvár in Transylvania (now Cluj in Rumania). Later, from 1895 to 1913, he was Professor of Geology and Palaeontology in the University of Budapest, and when pensioned in 1913 he was raised to the nobility with the title Dr. Bodrogi Koch Antal. Most of his work, presented in 220 papers, was done during the period 1872–1895 in Kolozsvár. In the andesites of Arany in Transylvania (now Uroiul in Rumania) he described various minerals of late volcanic origin, including the two he named pseudobrookite and szaboite. The Geological Society of London elected him a foreign correspondent in 1897 and a foreign member in 1903. (M. Pálfy, Földtani Közlöny, Budapest, 1929, vol. 58 (for 1928), pp. 7–14, 149–151, with portrait.)

Liversidge (Archibald) [1847–1927], for many years (1872–1907) Professor of Chemistry and Mineralogy in the University of Sydney, New South Wales, was born at Turnham Green, London, on November 17, 1847,[1] and died at his home at Kingston, Surrey, on September 26, 1927. He studied at the old College of Chemistry in 1866, and in 1867 entered the Royal School of Mines, London, with a Royal Exhibition, taking the associateship (A.R.S.M.) in mining and metallurgy in 1870. In that year he gained a science scholarship at Christ's College, Cambridge. During his first year at Cambridge he acted as deputy demonstrator in chemistry (for J. W. Hicks, afterwards Bishop of Bloemfontein), and before taking his degree he was

[1] The year of birth has been in some places erroneously given as 1846.

elected Professor of Chemistry and Mineralogy in the University of Sydney. The Cambridge degree of honorary M.A. was given to him in 1887. He did much for the advancement of science in Australia, where he occupied many public positions. He also accomplished a large amount of original work in chemistry and mineralogy; and after he returned to London in 1908 he continued to work in his private laboratory. His first paper, in 1870, was on supersaturated solutions, and in 1872, soon after his arrival in Sydney, he gave a description of the Barratta meteorite. Several other Australian meteorites were subsequently analysed and described by him. His excellent book, 'The minerals of New South Wales' (third edition, 1888), was an extension of an early paper in 1874 in the Transactions of the Royal Society of New South Wales.

A. Liversidge (in 1899).

Professor Liversidge was a keen collector and he showed his collection at several international exhibitions. The better examples of Australian gemstones he gave some years ago to the Australian Museum at Sydney, and the main part of his large collection of Australian minerals, ores, and rocks, together with many meteorites and sections of gold nuggets which he had figured and described, was bequeathed to the British Museum. Being a bachelor, he left endowments for scholarships to the University of Sydney, Christ's College at Cambridge, and the Royal School of Mines in London, and funds to the Royal Society of New South Wales, the Australian Association for the Advancement of Science, and the Chemical Society of London. He was an original (1876) member of our Society, and was elected F.R.S. in 1882. (Obituary notices in Nature, London, 1927, vol. 120, pp. 625–626; Journ. Roy. Soc. N.S.W., 1929, vol. 62 (for 1928), pp. 8–10 (reprinted from The Times, London, September 28, 1927); Sir T. W. E. David, Proc. Roy. Soc. London, Ser. A, 1930, vol. 126, pp. xii–xiv, with portrait).

Luquer (Lea McIlvaine) [1864–1930], tutor and associate professor of mineralogy in Columbia University, New York City, from

1887 to 1925, was born at Brooklyn, New York, on September 4, 1864, and died on January 30, 1930. In association with the late Professor A. J. Moses [1859–1906] at Columbia University he did some useful mineralogical work. Since then he published in 1908 a third edition of his book, 'Minerals in rock sections', which first appeared in 1898. He married a rich wife and had social duties to perform.

Maucher (Wilhelm) [1879–1930], mineral dealer in München (= Munich), was born at Winterstettenstadt in Württemberg on June 15, 1879, and died in München on May 4, 1830. After a school education in Württemberg, he entered the Mining Academy at Freiberg in Sachsen, where in 1901 he gained the diploma in engineering. A short time was spent in smelting works in Saxony and he then returned to the Freiberg Academy to succeed H. Zinkeisen as Faktor of the Mineralien-Niederlage, which had been primarily founded to supply the students with specimens and afterwards developed into a business for the sale of minerals generally. In 1909 he established a mineral business of his own in München: this will be carried on by his two sons. The many good specimens which since 1905 he supplied for the British Museum mineral collection were accompanied with detailed labels often with neat drawings of the crystals. While at Freiberg he issued pamphlets for the use of students, a very suggestive one dealing with the order of deposition of various minerals in metalliferous veins ('Die Bildungsreihe der Mineralien'. Freiberg, 1914). Later, in 1924, he wrote on the influence of gravity on the growth of crystals. The mineral maucherite (Ni_3As_2) was named after him by F. Grünling in 1913. His portrait appears in the group taken at the time of the Society's Jubilee in 1926 (Min. Mag., vol. 22, pl. 2).

Merrill (George Perkins) [1854–1929], for many years Head Curator of Geology in the United States National Museum at Washington, D.C., was born on May 31, 1854, at Auburn in Maine, and he died there suddenly of a heart attack on August 15, 1929. After graduating at the University of Maine in 1879, he became in 1881 curator of mineralogy in the United States National Museum, and in 1897 head curator of the division of geology, an appointment which he held till the end. There he did remarkably good work in gathering together material on a large scale and displaying it

effectively. The economic collections which he installed are probably the best that are to be seen in any museum. In connexion with this work he wrote a useful book, 'The non-metallic minerals, their occurrence and uses' (1904 and 1910), which was one of the first and best books on economic minerals; also 'Stones for building and decoration' (three editions, 1891, 1897, and 1903), and 'Treatise on rocks, rock-weathering and soils' (1897, 1907). Excellent handbooks and descriptive catalogues were also issued of the important collections of gems and precious stones (1922) and of meteorites (1916). Other useful books are his 'History of American geology' (1906) and 'History of American state geological and natural history surveys' (1920), in which are collected many biographical details and portraits. In addition to all this work, he had for many years made a special study of meteorites, and in a series of sixty papers he had described as many as forty new falls. He did much to make the national collection one of the great meteorite collections of the world. The meteoritic mineral merrillite was named after him. From 1893 till 1916 he was also Professor of Geology and Mineralogy in the George Washington University. A complementary dinner was given to Dr. Merrill on the occasion of his seventy-fifth birthday on May 31, 1929, an account of which appeared in 'Science' (New York, 1929, vol. 70, pp. 122–123), and in sad contrast the same journal gave a few weeks later an obituary notice (vol. 70, pp. 274–275). (M. Benjamin, Amer. Journ. Sci., 1929, ser. 5, vol. 18, p. 364.)

George P. Merrill (in 1927).

Michel (Léopold Jean) [1846–1919] was born on July 20, 1846, at Riaucourt, Haute-Marne, where his father was manager of the ironworks, and he died on October 1, 1919. He entered the School of Mines in Paris in 1867 and had just finished his course when the war of 1870 broke out; he also went through the war of 1914–1918, after which he was promoted to officer of the Légion d'honneur. For some years after 1870 he was engaged in the working of iron-ores,

but gave this up to enter the laboratories of C. Friedel and Hautefeuille in the University of Paris, where in 1880 he became assistant and later (1900) assistant professor in mineralogy. A thesis for the degree of doctor in 1889 dealt with the crystallography of a number of tungstates, molybdates, selenates, and tellurates. L. Michel prepared artificially a number of minerals, and described hautefeuillite as a new species. He was twice (1903 and 1919) President of the French Mineralogical Society. This belated notice is based on one by J. Orcel, Bull. Soc. Franç. Min., 1929, vol. 52, pp. 8–14, with bibliography.

Milch (Ludwig) [1867–1928], since 1917 Professor of Mineralogy in the University of Breslau, was born at Breslau on August 4, 1867, and died there from a stroke on January 6, 1928. Educated at Breslau, he was assistant there in mineralogy and geology, and in 1906 succeeded E. Cohen as Professor of Mineralogy in the University of Greifswald, returning to Breslau in 1917 as successor to C. Hintze. His main work was petrographical—on the diabase-schists of the Taunus Mts. (1889) 'Verrucano' of the Alps (1892, 1896), rocks from Paraguay (1893, 1895), Sumatra (1899), &c. He described as new minerals lossenite and hintzeite; the latter, named after C. Hintze, was also independently described in the same year and curiously named heintzite. Milch was Victor Goldschmidt's first pupil at Heidelberg, and he acted as editor of the 'Festschrift Victor Goldschmidt' (1928), which was completed though not issued at the time of his sudden death.

Nordenskjöld (Nils Otto Gustaf) [1869–1928], explorer, nephew of Baron A. E. Nordenskjöld, was born at Sjögelö, Småland, on December 6, 1869, and died as the result of a street accident on June 2, 1928. He studied at Upsala, first chemistry and afterwards geology, and from 1894–1906 he was assistant in mineralogy and geology. Since 1905 he was Professor of Geography and Ethnography in the University of Göteborg (= Gothenburg). His early papers were chemical and on the crystallography of organic compounds, and he gave a chemical analysis of the Lundsgård meteorite. Other rather later papers were petrographical and on ore-deposits, and a good account of the mineral edingtonite from Sweden. In 1895–1897 Otto Nordenskjöld was leader of the Swedish expedition to the Magellan territories, and in 1901–1903 of the Swedish Antarctic

expedition. (A. Hamberg, Geol. För. Förh. Stockholm, 1928, vol. 50, pp. 469–471. H. R. Mill, Nature, London, 1928, vol. 121, pp. 1026–1027.)

Pearce (Richard) [1837–1927], a successful metallurgist, was born at Barripper, near Camborne in Cornwall, on June 29, 1837, and died in London on May 18, 1927. Leaving school at the age of fourteen he worked with his father as a tin-dresser at the Dolcoath mine, but attending evening classes at the Truro Mining School he soon advanced himself to the position of assistant in chemistry. When the school closed in 1848 he returned to Dolcoath as assayer. With another revival of the Cornish mining schools in 1858 he started classes at the St. Just centre and during the winter at the Royal Institution of Cornwall. During that period of teaching he studied for a year (1859–1860) at the Royal School of Mines in Jermyn Street, London, under John Percy and A. W. von Hofmann. In 1865 he was commissioned to erect a smelter at Swansea in South Wales, and in that connexion he visited the works at Freiberg and Eisleben in Germany, where he first met S. F. Emmons. He visited Colorado in 1871 and migrated there in 1872 in the early days of mining in that region. There he erected smelters at Empire, Black Hawk, Argo near Denver, and at Butte in Montana. Large quantities of silver and gold were extracted from the copper ores by a new process devised by him. With the group of well-known men, W. F. Hillebrand, Whitman Cross, and S. F. Emmons, he was one of the founders, in 1882, of the Colorado Scientific Society, of which he was twice President. In 1885 he was appointed British Vice-Consul at Denver. In 1889 and 1890 he was President of the American Institute of Mining Engineers, and in 1890 was given the honorary degree of Ph.D. of Columbia University, New York City. Returning to England in 1902, he erected a smelter at Bootle near Liverpool for the treatment of Bolivian and Nigerian tin ores [see Min. Mag., vol. 19, p. 116], and he finally settled in London in 1915. He was

Richard Pearce (in 1916).

President of the Royal Institution of Cornwall in 1908–1909 and of the Royal Geological Society of Cornwall in 1905–1906.

Dr. Richard Pearce, during the course of a busy life as works manager, contributed many short papers and notes on minerals and crystallized furnace products, particularly in the Proceedings of the Colorado Scientific Society and in Cornish journals, and in 1907 he wrote on cassiterite pseudomorphs from Bolivia in this Magazine. In 1884 he noticed the presence of crystallized copper arsenates in the cargoes of ore sent for smelting from the Tintic district in Utah; and as long ago as 1871 he discovered pitchblende in Colorado, a mineral which he had previously found in Dolcoath mine, Cornwall. The mineral vandiestite was first described by him in 1898, and pearceite was named after him by S. L. Penfield in 1896. He had for many years been a generous donor of specimens to the mineral collection of the British Museum, and in 1924 he gave a handsome contribution to the publication fund of our Society, of which he had been a member since 1880. He was a Fellow of the Geological Society of London since 1869.

Ramsay (Wilhelm) [1865–1928], Professor of Geology and Mineralogy in the University of Helsingfors (= Helsinki), was born at Dragsfjärd, Finland, on January 20, 1865, and died on January 8, 1928. He was of Scottish descent from a branch of the Dalhousie Ramsays that settled in Finland in the sixteenth century. His mother was a daughter of G. S. Tham, Director of the Mining School at Falun in Sweden, where his father had been a student. After studying under F. J. Wiik at Helsingfors, he derived much benefit under W. C. Brøgger in the Technical High School at Stockholm (1885–1887), and he afterwards worked for short periods at the Universities of Berlin (under C. Klein), München (P. Groth), Heidelberg (H. Rosenbusch), Wien (G. Tschermak), Göttingen (T. Liebisch), and Paris (F. Fouqué). His first paper, in 1885, was on the variations in the optical characters of milarite with changes of tem-

Wilhelm Ramsay.

perature, and he did important work on the pleochroism and absorption of light in epidote. As geologist he took part in seven Finnish expeditions (1887–1914) to the Kola peninsula in Russian Lapland, where in the nepheline-syenite districts he discovered new minerals and new rock types. A mineral from there has since (1922) been named ramsayite. He also did exploration work in the Kanin peninsula and in Karelia in northern Russia, and was an authority on the geology of Fennoscandia. After acting as assistant and as deputy he succeeded his old teacher F. J. Wiik in 1899, after whom he had named the mineral wiikite. (J. J. Sederholm, Årsbok Soc. Sci. Fennica, 1928, vol. 6 B, no. 6, 27 pp., with portrait. L. H. Borgström, Förh. & Meddel. Svenska Tekniska Vetenskapsakad. i Finland, 1929, no. 5 (7), 26 pp., with portrait. A. Hamberg, Geol. För. Förh. Stockholm, 1928, vol. 50, pp. 111–112.)

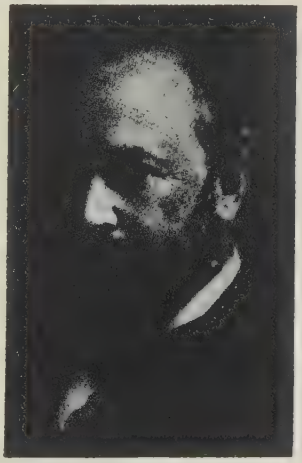
Roccati (Alessandro) [1872–1928] was born in Paris on August 1, 1872, of Piedmontese parents, and died on August 14, 1928 at Carmagnola in Piemonte, of which town he was mayor for several years. He studied in France and graduated at Torino, where in the Mineralogical Institute of the University he acted as voluntary assistant to G. Spezia. He was also assistant in applied geology in the Royal School of Engineering at Torino, and in 1908 was placed in charge of the laboratory of mineralogy, lithology, and constructional materials. He made an exhaustive study of the crystalline rocks of the Italian Alps, and in this connexion described various mineral occurrences. As geologist and mineralogist he accompanied the Duke of Abruzzi's expedition in 1906 to Uganda and Mt. Ruwenzori, and he also described the rocks collected on the duke's expedition to the Himalayas and the Karakoram Mts. In Brazil he examined the zirconia deposits, and he edited and published J. B. de Araujo Ferraz's fragmentary notes for a mineralogy of Brazil [Min. Abstr. **3**–446]. (A. Pelloux, Bull. Soc. Franç. Min., 1929, vol. 52, pp. 71–73.)

Scacchi (Eugenio) [1854–1929], Professor of Mineralogy and Director of the Mineralogical Museum in the University of Napoli, was born on October 8, 1854 and died on February 8, 1929. He was the son of Arcangelo Scacchi (1810–1893), who was professor at Napoli since 1842. After acting as assistant in mineralogy at Napoli from 1880, he was assistant professor at Genoa in 1890, returning to Napoli in 1891, where he was appointed full professor in 1895.

Compared with the large amount of important work done by his father, his published work was small in amount, his few papers, published mostly during the eighties of last century, dealing mainly with Vesuvian and other Italian minerals and the crystallography of organic compounds and fluomolybdates. (F. Zambonini, Rend. R. Accad. Sci. Fis. Mat. Napoli, 1930, ser. 3, vol. 35 (for 1929), reprint 3 pp., with portrait.)

Schafarzik (Ferenc = Franz) [1854–1927], for many years Professor of Mineralogy and Geology in the Polytechnic at Budapest, was born at Debreczen in Hungary on March 20, 1854, and died on September 5, 1927. After studying in the University of Budapest, he was assistant there (1876–1882) to J. Szabó, and from 1882 he worked for twenty-two years on the staff of the Geological Survey of Hungary. From 1891 he was also privat-docent in the Polytechnic where in 1904 he succeeded S. Schmidt as professor, retiring in 1926. He wrote many papers on the geology and petrography of Hungary, especially of the southern Carpathians, and also a few on minerals. The mineral schafarzikite was named after him by J. S. Krenner in 1921. (A. Vendl, Math. Naturwiss. Ber. aus Ungarn, 1928, vol. 34 (for 1926–1927), pp. 5–6. K. Roth von Telegd, Földtani Közlöny, Budapest, 1929, vol. 58 (for 1928), pp. 16–23, 152–160, with portrait.)

Schoenflies [1] (Arthur Moritz) [1853–1928], mathematician, was born at Landsberg on the Warthe in Preussen on April 17, 1853, and died at Frankfurt am Main on May 27, 1928. He graduated at Berlin in 1877 and after some years of school teaching he was Professor of Mathematics successively at Göttingen, Königsberg, and since 1911 at Frankfurt am Main. At the last place he was Rector of the new University during the difficult years of the war. His many mathematical papers dealt mainly with geometrical problems,



A. Schoenflies.

[1] The name has sometimes been written Schönflies, and incorrectly as Schönfliess, but he himself always used the form Schoenflies.

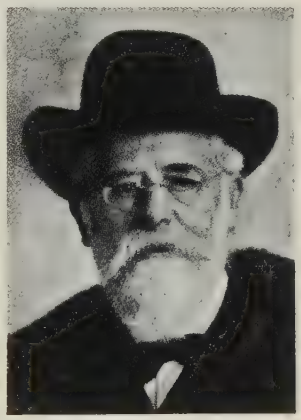
and in 1887 he published one on groups of movements. In his classic book 'Krystallsysteme und Krystallstructur' (1891) he established independently of E. S. Fedorov (1890) and W. Barlow (1894) the 230 space-groups. The notation for the space-groups which he then proposed is now universally used in connexion with the intensive work that is being done on crystal-structure by the aid of X-ray methods. What is really a second edition of his earlier book appeared in 1923 under the title 'Theorie der Kristallstruktur' [Min. Abstr. vol, 2, p. 145].

Schulz (Karl) [1885–1928] was born at Berlin on September 17, 1885, and died on May 11, 1928. He studied at Berlin under C. Klein and graduated in 1909 with a dissertation on the petrography of Korea. After acting for a short time as assistant to T. Liebisch in the Mineralogical Institute of the University of Berlin, he spent some years as a schoolmaster, returning again in 1924 as a voluntary assistant in the Mineralogical Institute. His elaborate compilations of the thermal constants of minerals and rocks were published in the Fortschr. Min. Krist. Petr., vols. 2–9 (1912–1924). The section on phosphates, &c., in C. Hintze's 'Handbuch der Mineralogie' was contributed by him, and he wrote on educational methods in mineralogy. (W. Hartwig, Fortschr. Min. Krist. Petr., 1929, vol. 13, pp. 313–320, with bibliography.)

Toborffy (Zoltán) [1883–1927], privat-docent in the University and teacher in the City High School at Budapest, was born on March 31, 1883, and died on May 18, 1927. Between 1903 and 1912 he produced a number of good mineralogical papers, and in 1916 presented a prize essay on the micas before the Hungarian Society of Natural Sciences [Min. Abstr. vol. 1, p. 392]. (Földtani Közlöny, Budapest, 1927, vol. 57, pp. 2, 93.)

Tschermak (Gustav *von*) [1836–1927], the veteran Austrian mineralogist, was born at Litovel (= Littau) near Olomouc (= Olmütz) in Moravia (= Morava = Mähren) on April 19, 1836, and died at Wien (= Vienna) on May 4, 1927, at the advanced age of 91. His father Ignaz Czermak (or rather Čermák, meaning in Czech, redbreast, robin) was a tax-collector. As a schoolboy at Olomouc he was marked by his independence and enterprise, and he there started a German students' union against the threatened Slav agitation and also a natural history society. It was at that time

that he adopted the German form of spelling of his name. In 1856 he went to the University of Wien, where he later became assistant to F. X. M. Zippe. Graduating at Tübingen in 1860, he returned to Wien as privat-docent in chemistry and mineralogy. In 1862 he was appointed second curator, and in 1868 director, of the Hof-mineralien-Kabinet in Wien, from which position he retired in 1877 when the collection became part of the Royal Natural History Museum. During that period he made important additions to the famous mineral and meteorite collections. In 1868 he was extra Professor of Petrography and from 1873 ordinary Professor of Mineralogy and Petrography in the University of Wien. On the occasion of his retirement from active teaching in 1906 he was raised to the rank of the nobility with the hereditary title Edler von Seysenegg, and his name sometimes appears in the form Tschermak-Seysenegg. But after his retirement he still continued to work almost every day in the Mineralogical Institute. The war left him in straitened circumstances, and help was very generously given to him until the end by American mineralogists through Prof. E. S. Dana, who had studied at Wien in 1873–1874.



G. Tschermak (in 1906).

Tschermak's earlier papers were petrographical, the first, in 1856, on trachytes from Moravia, and a monograph in 1867 (published afterwards as a book in 1869) on the porphyritic rocks of Austria. In the Royal Society's 'Catalogue of Scientific Papers' he is credited with 130 titles up to the year 1900, these dealing mainly with minerals and meteorites. He produced a number of classic papers on the chemical constitution of various groups of silicate minerals, the results of which have been familiar in the text-books for more than a generation past. These include the plagioclase felspars (1865), the pyroxene and amphibole groups (1871), the micas (1877, 1878), zoisite-epidote group (1880), scapolites (1884, 1886), brittle micas (1889), chlorites (1890), vermiculites (1891), tourmaline (1899), zeolites (1917, 1918), and idocrase (1918). In later years, with the help of his pupils (including his daughter Silvia Hillebrand) he

endeavoured to determine the composition of silicic acids isolated from natural silicates. He is also well known through the important journal he founded, which as 'Mineralogische Mittheilungen' was first issued (1872–1877) in quarto form as a supplement to the 'Jahrbuch' of the Austrian Geological Survey, followed by the new series 'Mineralogische und Petrographische Mittheilungen' in octavo form from 1878 till 1889, since when it was continued under the editorship of F. Becke as 'Tschermaks Mineralogische und Petrographische Mitteilungen'. His 'Grundriss der Mineralogie' for schools was published in 1863, and his well-known 'Lehrbuch der Mineralogie' first appeared in parts during 1881–1884, reaching a sixth edition in 1905, and a ninth edition by F. Becke in 1923.

Tschermak was an honorary member of many academies and scientific societies; of our Society since 1879, and of the Geological Society of London since 1875. He was Rector of the University of Wien in 1893. In 1901 he was one of the founders of the Wien Mineralogical Society and its first President. The mineral named after him 'tschermakite' by F. von Kobell in 1873 was afterwards proved to be identical with albite. Of the minerals named by Tschermak himself mention may be made of ludwigite and the meteoritic felspar maskelynite.

A 'Tschermak-Heft' with portrait was issued in 1906 (Tsch. Min. Petr. Mitt., vol. 25) on the occasion of his seventieth birthday. (Obituary notices by F. Becke, Tsch. Min. Petr. Mitt., 1928, vol. 39, pp. i–x; Almanach Akad. Wiss. Wien, 1927, pp. 187–195. J. W. Evans, Nature, London, 1927, vol. 120, pp. 195–196. A. Himmelbauer, Verh. Geol. Bundesanstalt, Wien, 1927, pp. 149–151. B. Mauritz, Földtani Közlöny, Budapest, 1929, vol. 58 (for 1928), pp. 27–28, 161–162. E. S. Dana, Amer. Journ. Sci., 1927, ser. 5, vol. 14, p. 87; Amer. Min., 1927, vol. 12, p. 293, with portrait.)

Tully (Bristow John) [1879–1929], gem expert and jeweller, was a member of our Society since 1921 and of the Geological Society of London since 1906. He was born in London on March 2, 1879, and died suddenly on February 12, 1929. Educated at Barker's School, Windsor, and at King's College, London, he early entered the jewellery trade and attended evening classes at the London County Council School of Arts and Crafts, where in 1901 he was awarded a bronze medal for goldsmith's work. He took an active interest in the scientific aspects of gem-stones, and under the auspices of the

National Association of Goldsmiths he gave instruction classes on gemmology, acting later as examiner for giving certificates and diplomas to working jewellers. A very useful form of refractometer especially suitable for determining gem-stones was designed by him and described in this Magazine (vol. 21, p. 324).

Vaux (George, *Junior*) [1863–1927], lawyer and mineral collector, was born at Philadelphia on December 18, 1863, and died at Bryn Mawr, Pennsylvania, on October 24, 1927. He was the ninth George Vaux of an old Quaker family. The first George was deprived of his property in 1661 after the restoration of Charles II, and three later Georges were physicians in Reigate and London. A branch of the family went to Philadelphia in 1771, where later the seventh George became a prominent lawyer. George Vaux, Jr., was distinguished by his many legal, religious, educational, scientific, and philanthropic activities. Since 1907 he was chairman of the Board of Indian Commissioners and he had an intimate knowledge of the American Indians. Since 1894 he was treasurer and later a trustee of the Academy of Natural Sciences of Philadelphia. He collected minerals as a boy, following the example of his uncle William S. Vaux, whose fine collection was bequeathed to the Philadelphia Academy in 1882, where the mineral collection is still known as the William S. Vaux collection. This has been considerably added to through the influence of George Vaux, Jr., especially during recent years by the collecting expeditions of S. G. Gordon to Bolivia, Peru, Chile, and Greenland. His own private collection was housed in a special wing of his beautiful home at Bryn Mawr, Pennsylvania, where it is still kept in order by Mrs. Vaux for the benefit of her two sons (one of them the tenth George Vaux). The writer was privileged in 1924 to enjoy the kind hospitality of the Vaux family and was much impressed with the orderly arrangement of the large collection and the fine display made by suites of specimens. Specially noteworthy is the fine series of proustites from Chañarcillo, Chile,

George Vaux Jr.

which are no doubt the finest in existence. They were acquired by William S. Vaux after the Philadelphia Exhibition of 1876, and include a single crystal six inches in length and a twin group resembling a cross. Mr. Vaux was for several years President of the Philadelphia Mineralogical Society, and he was a member of our Society since 1922. He published only three short mineralogical papers and a few on the glaciers of British Columbia, but his name is perpetuated in mineralogical literature by the Bolivian minerals vauxite, paravauxite, and metavauxite. (S. G. Gordon, Amer. Min., 1928, vol. 13, pp. 97–102, with portrait and bibliography.)

Wagner (Percy Albert) [1885–1929], South African geologist, was born at Richmond, Cape Province, on October 18, 1885, and died at Johannesburg on November 11, 1929, after a short illness from enteric fever followed by pleurisy and pneumonia. He was educated at the South African College in Cape Town and the School of Mines and Technology in Johannesburg, taking the Diploma in Mining Engineering in 1906. He then went to the Mining Academy at Freiberg, Saxony, where he studied under R. Beck, and he also studied under H. Rosenbusch at Heidelberg. His dissertation for the degree of Doctor of Engineering was republished during the same year in an enlarged form as a book 'Die Diamantführenden Gesteine Südafrikas' (Berlin, 1909). He also wrote early papers on the diamond fields of South-West Africa, and in 1914 produced a classic work 'The diamond fields of Southern Africa'. His last work 'The platinum deposits and mines of South Africa', issued just before his death, will also remain a classic. On his return to South Africa he acted for a short time as Professor of Geology in the Transvaal University College, and was then engaged by the De Beers Consolidated Diamond Mines to carry out special investigations in South-West Africa and Southern Rhodesia. Afterwards he practised as a consulting geologist in Johannesburg and Pretoria.

Percy A. Wagner.

In 1919 he was appointed for economic work on the Geological

Survey of the Union of South Africa, from which he resigned in 1927 to become consulting geologist to the Union Minerals Exploration Syndicate. Besides many original geological papers and memoirs he produced a large number of reports on economic minerals, and in 1916 a useful summary of the geology of South-West Africa. Several of the guide-books issued for the meeting of the International Geological Congress in South Africa in 1929 were prepared by him, and he will be remembered by many of the visitors for the energy and enthusiasm with which he lead several of the excursions. By his untimely death at the age of forty-four South Africa has lost an energetic and brilliant worker. (A. W. Rogers, Trans. Geol. Soc. South Africa, vol. 33, for 1930. A. L. du Toit, Geol. Mag. London, 1930, vol. 67, pp. 191–192. A. M. Bateman, Econ. Geol., 1930, vol. 25, pp. 88–90.)

White (Franklin) [1849–1928], Mining Engineer, and since 1920 a member of our Society, was born at Cowes in the Isle of Wight and died on October 18, 1928. He had been manager of gold mines in Colombia, South America, and he went in the early days (1889) to Rhodesia. At Bulawayo he took part in the foundation of the Rhodesia Scientific Association (1899) and of the Rhodesia Museum (1901), being several times President of the Association and on the committee of the Museum. He wrote early accounts of the ruins at Zimbabwe and other places in Rhodesia, the human remains in the caves at Broken Hill, and on stone implements. For many years he had been a generous donor to the mineral collection of the British Museum of specimens that he had collected in many parts of the world in connexion with his mining work.

Wichmann (Carl Ernest Arthur) [1851–1927] was born at Hamburg on April 9, 1851, and died there on November 28, 1927. He graduated at Leipzig with a dissertation on pseudomorphs of cordierite, and was assistant in the Mineralogical Institute there from 1873 to 1879. In 1879 he was appointed Professor of Mineralogy and Geology in the University of Utrecht, Holland, retiring in 1922. A. Wichmann led several expeditions to the Dutch East Indies, and wrote papers on the geology and petrography of many of the islands. In 1875 he described nepheline-basalt from the Sandwich Islands and in 1893 leucite-rocks from Celebes. (Verslag Afd. Natuurk. K. Akad. Wetensch. Amsterdam, 1927, vol. 36, pp. 1193–1196.)

Wills (Joseph Lainson) [–1929], the last original (1876) member of this Society, died in New York City on February 28, 1929. He was a consulting chemist practising since before 1898 in New York, and previous to that time he had lived for some years in France. He was a Fellow of the Chemical Society of London since 1872. His only paper appears to be one on the commercial aspects of 'Natural phosphates' which appeared in the 'Ottawa Naturalist' in 1892 and was reprinted in the 'Chemical News' in the same year.

Later deaths are those of:

Busz (Karl) [1863–1930].

Elsden (James Vincent) [1856–1930].

Evans (John William) [1857–1930.]

Termier (Pierre) [1859–1930].

Cupriferous melanterite from the Skouriotissa mine, Cyprus.

By Max H. Hey, B.A., B.Sc.
Assistant-Keeper in the Mineral Department of the British Museum of Natural History.

[Read November 4, 1930.]

A MAGNIFICENT specimen of melanterite has recently been presented to the British Museum by the generosity of Mr. James L. Bruce, Resident Director of the Cyprus Mines Corporation, through the agency of Prof. C. Gilbert Cullis of the Royal School of Mines, London. The specimen (B. M. 1930,439) appears to merit a short description, for it consists of a group (35 by 25 cm.) of enormous greenish-blue crystals (up to 18 by 13 cm.) of a very unusual habit, being tabular to *b*(010). The photograph (fig. 1) can convey only a very inadequate idea of the beauty of the group, and it is most fortunate that the generous action of Mr. Bruce and the care of Prof. Cullis have ensured its preservation and exhibition for the pleasure of many.

Mr. Bruce states that the specimen 'was found in the Skouriotissa mine in the 820-foot level [i. e. 820 feet above sea-level] at a point 160 feet almost due east from the shaft known as the circular shaft in an ancient caved stope in the ore body', and 'had formed like a stalactite under a crack in the roof'. The cavity in which it was found 'was probably filled by a mixture of nitrogen gas and sulphur dioxide'. The Skouriotissa mine is near the Skouriotissa monastery, about 3 miles south-east of Lefka, Nicosia district, Cyprus, and the ore is a cupriferous pyrites. There is no doubt that the Skouriotissa mine was one of the most important of the ancient mines of Soli, developed by the Romans, and perhaps, even earlier, by the Phoenicians. The site of the port of Soli is only 5 miles off. There are large accumulations of slag, and ancient workings are discovered from time to time.[1] It was in one of these ancient workings that the specimen was found.

[1] C. G. Cullis and A. B. Edge, Report on the cupriferous deposits of Cyprus. London, 1922, p. 15. [Min. Abstr., vol. 2, p. 549.]

Incipient decomposition (efflorescence and oxidation) is visible at one or two places on the specimen, in the shape of yellowish-white dots and patches. To check this, the specimen had been coated with shellac shortly after its removal from the mine, but for greater security, it has now been placed in a moist atmosphere under a glass dome. The dome is made air-tight by standing it in a groove filled with mercury in a well-varnished wood block.

Because of their peculiar habit, the crystals appear anorthic, and this, together with their blue colour, suggesting chalcanthite, made it desirable to confirm their identity by goniometry and analysis. On account of the shellac coating, an accurate analysis could not be made, but optical examination showed the crystals to be monoclinic, and the goniometric measurements agree with melanterite. A partial analysis showed the presence of 2·15 % CuO, corresponding to 7·72 % $CuSO_4.7H_2O$ in isomorphous mixture with $FeSO_4.7H_2O$. This amount of copper is not sufficient to call the mineral pisanite.[1]

The goniometric study could not be made with any great accuracy, owing to the shellac coating and the large size of the crystals. One small crystal was detached, the shellac dissolved off with alcohol, and the crystal measured on the three-circle goniometer, in face-adjustment about the most perfect face, which turned out to be $v(101)$. Two of the largest crystals were measured with an improvised contact-goniometer of card strips, to ensure that the crystal edges were not damaged. The measured values agree satisfactorily with the calculated, and show the presence of five new crystal-forms. Examination with a pair of nicols held in the hand shows the extinction-angle on $b(010)$ to be about the expected value, further confirming the orientation adopted.

On the small crystal (fig. 2) there are present, besides $v(101)$, $r(111)$, $o(011)$, $c(001)$, $m(110)$, and $t(\bar{1}01)$, and one face each of the new forms $x(161)$ and $y(\bar{2}31)$. The large crystals are differently developed and show $b(010)$, $m(110)$, $a(100)$, $v(101)$, $r(111)$, $w(103)$, $o(011)$, $c(001)$, $s(\bar{1}05)$, $t(\bar{1}01)$, and $\sigma(\bar{1}21)$. In addition, one of the crystals (fig. 3) shows a face of the new form $q(\bar{1}02)$; and the other (fig. 4) shows a small facet (about 3 by 1 mm.) of $g(\bar{1}12)$, also a new form.

A face of $b(010)$ is not present on the small crystal, whereas on the two large crystals measured, and on most of the others, it predominates, but is strongly curved. Beginning at one extremity of

[1] Cf. H. F. Collins, Min. Mag., 1923, vol. 20, p. 32.

the crystal, b is strictly in the calculated position, but as the other extremity is approached it takes on a curvature about the zone-axis [001], remaining strictly in this zone; it finally merges into a plane portion, making an angle of 10° with $b(010)$, which constitutes a fifth new face $\beta(150)$. The distribution of β and of the curved tracts

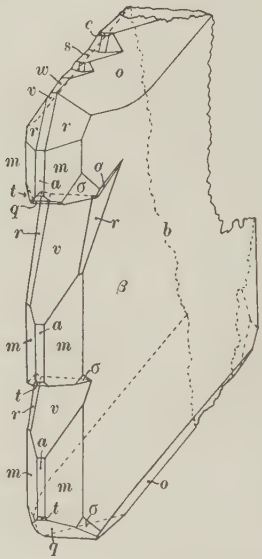
FIG. 1. Group of large crystals of melanterite from the Skouriotissa mine, Cyprus. About 2/7th natural size.

differs on different crystals. The four faces of the form β and the corresponding curved tracts are never all developed. One of the measured crystals (fig. 4) has $\beta(1\bar{5}0)$ and $\beta(\bar{1}50)$ and the corresponding curved transitional regions; the other has $\beta(1\bar{5}0)$ and $\beta(150)$ (fig. 3). It is largely this peculiarity of distribution, which is shared by the other crystals on the specimen, that gives the crystals an anorthic appearance at first glance.

But this is only a part of the difference that this specimen shows from the usual habit of melanterite. Instead of a predominant development of $m(110)$ and $c(001)$, c is present as very small, narrow strips, and m is comparatively small. Next to b and β, $o(011)$ is the largest face, while $v(101)$, $r(111)$, $s(\bar{1}05)$, $t(\bar{1}01)$, and $\sigma(\bar{1}21)$ are

fairly large; $q(\bar{1}02)$, $a(100)$, $w(103)$, and $g(\bar{1}12)$ never attain any size.

The measurements made on the three-circle goniometer fall simply into four zones, with the corresponding interzonal angles. The measurements on the larger crystals are mainly interfacial, but several facets were too small for accurate measurements to be made



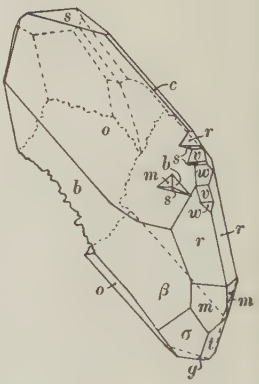


Fig. 2. Fig. 3. Fig. 4.

Fig. 2. Small measured crystal of melanterite. About 5 times natural size.

Figs. 3 and 4. Large measured crystals of melanterite. About 2/5th natural size.

in this way; instead, interzonal angles were measured, the contact-goniometer being fitted to the angles between suitable edges.

The derivation of a face-symbol purely from such interzonal angles by the ordinary methods of calculation is somewhat troublesome, but the graphical solution is simple. Thus for the facet g, we have $[\sigma t]\ [\sigma g] = 37°$ and $[sg]\ [\sigma s] = 11°$. First, we plot the stereographic pole of the zone $[\sigma t]$, P, then construct in the usual manner the circle of points distant 37° from P; let this cut the trace (cyclographic projection) of σ at Q_1 and Q_2. One of these points must be the stereographic pole of the zone $[\sigma g]$. We draw in the zones, and construct similarly two zones containing s and lying 11° from $[s\sigma]$.

A variety of solutions results from the intersection of the four zones so constructed, but only one lying in the triangle $st\sigma$, which is known to be the position of g. Proceeding to the gnomonic projection, the indices of g are immediately read off as $(\bar{1}12)$. The solution is quite definite. The true interzonal angles are then calculated in the usual manner, and found to be 39° 23′ and 11° 30′.

In the following table of angles measured on the three crystals represented in figs. 2–4, the calculated values have been derived from the constants, $a:b:c = 1{\cdot}1828:1:1{\cdot}5427$, $\beta = 75° 44\frac{1}{2}'$, determined by V. von Zepharovich in 1879 on artificially prepared crystals of hydrated ferrous sulphate, $FeSO_4.7H_2O$.

Interfacial angles.

	Fig. 2.	Fig. 3.	Fig. 4.	Calculated.
Zone $ac = [010]$:				
$v(101):t(10\bar{1})$ ...	74° 0′	—	75°, 72°	74° 30′
$v(101):c(001)$ ...	45	43°	45	43 44
$v(101):a(100)$ ...	—	32	35	32 $0\frac{1}{2}$
$c(001):q(\bar{1}02)$ ...	—	39	—	36 $58\frac{1}{2}$
$c(001):s(\bar{1}05)$ ...	—	17	16	14 $15\frac{1}{2}$
$c(001):w(103)$ ...	—	21	21	20 50
Zones $mov = [11\bar{1}]$ and $[1\bar{1}1]$:				
$v(101):o(\bar{1}21)$ ...	87	—	84, 83	83 22
$v(101):o(011)$ ...	67, 66°	—	67	66 19
$v(101):m(1\bar{1}0)$ ...	55°, 56° 20′	—	55	56 7
$v(101):y(23\bar{1})$ ...	73° 43′	—	—	73 10
Zone $brv = [\bar{1}01]$:				
$v(101):r(111)$ ...	$38\frac{1}{2}$, 40°	40	40, 39	39 $16\frac{1}{2}$
$v(101):x(161)$ ...	78° 28′	—	—	78 29
$v(101):b(010)$ ...	90	90	90	90 0
Zone $bot = [101]$:				
$t(\bar{1}01):o(\bar{1}21)$ ...	—	67	65, 65	64 22
$t(\bar{1}01):b(010)$ ...	—	—	88, 89	90 0
Zone $boc = [100]$:				
$b(010):o(011)$ ...	—	33	34, 34 / 36, 37	33 $46\frac{1}{2}$
$b(010):c(001)$ ...	—	90	—	90 0
$o(011):o(0\bar{1}1)$ ...	—	114, 114°	112	112 27
Zone $bma = [001]$:				
$b(010):a(100)$ ...	—	—	90	90 0
$b(010):\beta(150)$ ...	—	10	10	9 54
$m(110):m(1\bar{1}0)$ ...	—	98, 94	97	97 48
Zone $m\sigma = [\bar{1}11]$:				
$m(110):o(12\bar{1})$ ...	—	27	—	27 $14\frac{1}{2}$

	Interzonal angles.			
	Fig. 2.	Fig. 3.	Fig. 4.	Calculated.
On face $v(101)$:				
$ac[010] : mov[11\bar{1}]$...	65° 13′, 66°	—	—	65° 11′
$ac[010] : brv[\bar{1}01]$ ...	88 27	—	—	90 0
On face $\sigma(\bar{1}21)$:				
$\sigma t[101] : \sigma g[311]$ ...	—	—	37°	39 23
On face $s(\bar{1}05)$:				
$s\sigma[521] : sg[532]$ ...	—	—	11	11 30
On face $r(111)$:				
$rv[\bar{1}01] : r\beta[\bar{5}14]$ ...	—	9°	—	7 45
$ro[\bar{2}11] : r\beta[\bar{5}14]$ ...	—	18	—	15 30
On face $\beta(150)$:				
$\beta r[\bar{5}14] : \beta o[\bar{5}11]$ ...	—	28, 29°	—	26 57
$\beta r[\bar{5}14] : \beta o[\bar{5}1\bar{3}]$ ...	—	85	—	81 12
On face $m(110)$:				
$m\beta[001] : mo[\bar{1}11]$...	—	40	—	39 40

A simple method of observing the magnetic properties of mineral grains.

By Frank Smithson, Ph.D., F.G.S.

[Communicated by G. M. Davies; read November 4, 1930.]

In examining mineral grains either from sands or from crushed rocks it is frequently found that the electromagnet not only affords a means of separating certain minerals, but is also an aid to their identification. Yet an electromagnetic separation is rarely, if ever, complete, and minerals are frequently found to stray into fractions to which they do not rightly belong. As a result, a grain which, let us say, is found in the garnet fraction may be practically non-magnetic, and if we assume that its magnetic properties are similar to those of garnet, a misidentification may be made. It seems desirable, therefore, that there should be some means of testing the magnetic properties of a single grain.

For such testing of individual grains the writer has devised the following simple device, which has the further advantage that it can be used in places where the electromagnet is not available. A piece of cardboard about $1\frac{3}{4} \times 1\frac{1}{2}$ inch is bent over at one end so as to give a square $1\frac{1}{2} \times 1\frac{1}{2}$ inch (fig. 1). Two darning needles are heated to redness and allowed to cool slowly; they are then forced through the fold of the card about $\frac{1}{2}$ inch apart and fixed to the card with seccotine so that their points are close together. Pins and rubber bands may be used to hold the needles in position until the seccotine is dry.

The needles are then placed on a horseshoe magnet (fig. 2) and a strong magnetic field results between the points. It is convenient to have several pairs of needles with various distances between the points (e. g. 0·5, 1·0, 1·5 mm., &c.), and the distance may be noted on each card. It is also advisable that the needles should be marked N and S on the card, so that they are always placed against the corresponding poles of the horseshoe magnet. It will probably be found that after a little use the needles become magnetized and acquire greater lifting power. It might be thought that soft iron

wire should give more constant results, but with this material it is impossible to keep the points even approximately the same distance apart.

Grains to be tested are placed in a watch-glass and observed under the microscope as the needle points are brought near. It is usually advisable to immerse the grains in some liquid medium, such as

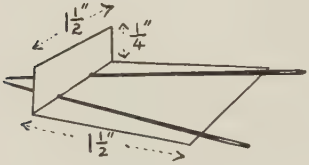


Fig. 1. Attachment for testing the magnetic properties of mineral grains.

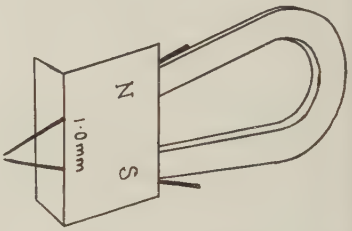


Fig. 2. Horseshoe magnet with card and needles attached.

benzol or bromoform. The readiness with which the grains respond depends upon several factors:

(*a*) The nature of the magnet.

(*b*) The distance between the needle points. The closer the points, the more powerful is the field.

(*c*) The magnetic properties of the mineral (and of its inclusions, if any).

(*d*) The size of the mineral grains. Small particles respond most readily.

(*e*) The nature of the medium, e. g. grains are lifted more readily in bromoform than in benzol.

The following table gives examples of results obtained. It will be noticed that the increase of sensitiveness obtained by substituting bromoform for benzol is most pronounced in the case of the lighter minerals. (Sp. gr., bromoform 2·9; biotite 3·1; tourmaline 3·2.)

In benzol.

Distance between needles.	0·5.	1·0.	1·5.	2·0.	4·0 mm.
Ilmenite ...	All the grains move before the needle is in contact with them.				Most of the grains move before contact.
Garnet ...	The grains are lifted readily when touched with the needle.				Grains lifted fairly readily when touched.
Tourmaline ...	The grains are lifted fairly readily when touched with the needle.			The grains are lifted, but not very readily, when touched.	
Staurolite ...	Smaller grains lifted easily when touched: larger grains lifted with difficulty.		Smaller grains lifted with difficulty when touched.		Very little result.
Biotite ...	Very little result.				
Monazite ...	Doubtful.	No result.			

In bromoform.

Distance between needles.	0·5.	1·0.	1·5.	2·0.	4·0 mm.
Garnet ...	The grains move before the needle is in contact with them.				Slight movement before contact.
Tourmaline ...	The grains move before the needle is in contact with them.				Slight movement before contact.
Staurolite ...	The grains are lifted readily when touched with the needle.			The grains are lifted, but not very readily, when touched.	
Biotite ...	The flakes when disturbed move slowly towards the needles.				Slight attraction.
Monazite ...	Slight tendency to lift.	Doubtful.	No result.		

The sources and grades of the materials used are as follows: Ilmenite, Trias, Yorkshire, 0·1–0·2 mm. Garnet, Estuarine series, Yorkshire, 0·1–0·2 mm. Tourmaline (brown), Trias, Yorkshire, 0·1–0·3 mm. Staurolite, Trias, Yorkshire, 0·1–0·2 mm. Biotite, Shore sand, Brittany, 0·3–0·7 mm. Monazite, Shore sand, Ceylon, 0·1–0·3 mm.

Studies on the zeolites.

Part I. General review.

By Max H. Hey, B.A., B.Sc.
Assistant-Keeper in the Mineral Department of the British Museum of Natural History.

[Read November 4, 1930.]

THE zeolites form a group of minerals of considerable interest by reason of their peculiar properties. In particular, their remarkable continuous dehydration curves, in part reversible, and the ready base-exchange of some members have attracted attention. But in spite of much work, many important characters remain quite uncertain. Many of the zeolites show variations in composition which are not recognized or are incorrectly interpreted by the accepted formulae. Optical investigation has all too rarely been made on analysed material, and little is known of the variation of the optical properties of most members with their composition, and practically nothing of the variations consequent on artificial base-exchange reactions. In spite of much work, conflicting views are still held as to the interpretation of the dehydration results. In some instances even the crystal-system is still uncertain.

In these circumstances the extensive series of zeolites in the British Museum collection, recently greatly augmented by Mr. F. N. Ashcroft, invites detailed study, and it is the author's purpose to take the various species one by one, making thorough optical and physical studies of analysed material and endeavouring to trace regularities in the variation in composition. In many cases the material studied will be the same as that used by Prof. W. L. Bragg and his co-workers in their studies of crystal-structure.

Before coming to the detailed examination of the various species, it seems desirable to review shortly the general characteristics of the zeolites, and their relations to other groups of minerals and to certain artificial products.

The zeolites form a well-defined group, generally regarded as hydrated silicates of aluminium and the alkalis or alkaline earths, with the notable characteristic that the molecular ratio Al_2O_3 : $(Ca,Sr,Ba,Na_2,K_2)O$ is always equal to unity. (Some authors include hydrated silicates such as apophyllite, which contains little or no alumina, and laubanite, in which the above ratio is not equal to unity, but these lack some of the characteristic properties of the zeolites proper, and are best regarded as a separate group.) It follows from this characteristic that $O/(Al+Si) = 2$; indeed the two ratios are only different ways of expressing the same thing. The former relation has been most generally recognized, but the latter has the advantage of being more related to the crystal-structure.

As Prof. W. L. Bragg has pointed out in a lecture before this Society (March, 1930), the silicates are in general built up of kations of the stronger bases, together with anions composed of silicon and oxygen, or of silicon, aluminium, and oxygen (boron and trivalent iron, chromium, and vanadium may probably also take part in the anion), and hydroxyl groups or water molecules. The anion is a non-polar bonded structure, in which silicon (or aluminium) and oxygen alternate, and may be a small, finite group, or may be infinitely extended in one, two, or three dimensions (strings, sheets, or blocks).

The last case is characterized by the ratio $O/(Al+Si) = 2$. It is exemplified by the various forms of silica; but kations cannot enter into such a structure unless alumina or other trivalent atoms replace part of the silicon, when kations enter to balance the electrovalence.

Mr. W. H. Taylor (1930) has shown that analcime does indeed exemplify such a structure. It consists of an infinite tridimensional anion in which silicon or aluminium and oxygen alternate, forming an open framework within which sodium ions and water molecules are arranged. The meshes of the anion framework are large enough to permit the passage of the water molecules and sodium ions, thus allowing of dehydration and base-exchange, while the strong non-polar bonds of the framework permit these reactions to take place without destruction of the structure.

A similar type of structure is probable for the other zeolites. On this basis, the zeolites may be defined as hydrated aluminosilicates of the alkalis and alkaline earths, having an indefinitely extended tridimensional anion, in consequence of which the atomic ratio $O/(Al+Si) = 2$. In most of them the composition varies considerably,

and in many the ratio Si/Al is variable, a fact not brought out by the usually accepted formulae, but the best analyses always show a close agreement with the above condition.

If such a view of the constitution of the zeolites be accepted, then apart from variations of the water-content two main variations are possible. On the one hand, the kations may vary, Ca being replaced by Sr or Ba, Na_2 or K_2, or vice versa. Until recently, this has been recognized as the principal variation in composition. But since Si and Al are structurally equivalent to a marked degree (see, for example, W. L. Bragg, 1930), variations in the Si/Al ratio are equally possible, provided the electrovalence is kept balanced by corresponding kationic variation.

This variation has commonly been overlooked altogether, or attributed to the presence of a few trisilicate (Si_3O_8) or disilicate (Si_2O_5) groups in place of orthosilicate (SiO_4) or metasilicate (SiO_3) groups—finite groupings of a kind which Prof. Bragg has shown to exist in a small minority of silicates only. G. Friedel (1896) suggested that a part at least of the silica in zeolites was present as adsorbed SiO_2 molecules, having no more essential function than he assigned to the water. He supported his view by experiments in which the silica content of a zeolite was changed by treatment with alkali silicate solutions. These experiments are probably to be explained by deposition of silica gel in cleavage and other fissures of the crystal. They may have a significance in the interpretation of the natural zeolites, but it is impossible to say how much, without very full studies of the variation in optical and other physical properties with the composition.

Recently, in 1925, A. N. Winchell has recognized the variation in the Si/Al ratio in some zeolites, and has pointed out that to a marked degree the increase of this ratio is accompanied by a replacement of alkaline earths (Ca,Sr,Ba) bv alkalis (Na,K), thus constituting an isomorphic replacement of the type familiar in the felspars, $CaAl \rightleftarrows NaSi$. In the author's opinion, however, Winchell has underestimated the extent of the replacement $Ca \rightleftarrows Na_2$, partly, perhaps, because in his care to exclude all doubtful analyses, he has restricted himself to a very small number of good analyses. If the replacement were strictly of the felspathic type, the number of kationic atoms in the unit cell would be constant. It will be the author's task to show that in many instances this is far from being the case, with material of unquestionable purity.

The author's theory is that the Si/Al ratio in a zeolite is governed principally by the Si/Al ratio in the magmatic solution from which it was deposited. The ratio of alkaline earths to alkalis (contracted for convenience to Ca/Na) is also, naturally, governed to some extent by the corresponding ratio for the solution, but it is markedly affected by a tendency for the number of kationic atoms in the unit cell to attain a characteristic integral value. As a rule, these two factors will clash more or less, and it is possible that the Si/Al ratio may be slightly modified in consequence.

But the actual Ca/Na ratio found in any specimen will not necessarily be that for the material as originally deposited, since the subsequent action of solutions may result in a replacement of Ca by Na_2 or vice versa. And not only may subsequently penetrating solutions alter the ratio, but so may the mother-liquor which laid down the zeolite, for the Ca/Na ratios in the solution and the crystal in equilibrium are not necessarily the same, so that Ca or Na may accumulate in the mother-liquor.

It is a possible explanation of the more markedly constant number of kations per unit cell found by Winchell that his carefully selected analyses included few of material that had been exposed to this subsequent action. For the action would probably also tend to render the material impure, and so exclude it from Winchell's consideration. If this is true, Winchell's curves enable us to eliminate the effect of subsequent action to a considerable degree, and offer us an indication of the great influence of the tendency to a constant number of kations.

Zeolites that do contain (within the limits of experimental error) the number of kations per unit cell characteristic for their species will be referred to as *Normal* zeolites.

It is to be emphasized that in consequence of their anion extending through the crystal, and its very strong, non-polar bonded structure, the zeolites cannot be expected to show the same behaviour as the great majority of inorganic salt hydrates. It is to the stability of this anion and its open structure that the remarkable dehydration phenomena are due, the one maintaining the structure after removal of the water, the other permitting the removal without disturbance of the structure. The same structural characteristics are also responsible for the notable hardness of the zeolites.

The dehydration relations are probably really fairly simple, as has been increasingly brought out by recent work. In some zeolites the

water may probably be all removed without any discontinuity at all; as dehydration proceeds, there is a tendency for the whole structure to shrink somewhat, provided the temperature is maintained high enough for a long enough period, and after such shrinkage, the re-absorption of water is prevented, or at least slowed. If, however, the dehydration is carried out at a low temperature in vacuo, the lattice-shrinkage ('Gitterreaktion') of Rinne (1920) and Scheumann (1921) is largely or entirely avoided, and the rehydration is rapid.

The dependence of the reversibility on the thermal history has been one of the most puzzling things about the dehydration phenomena of the zeolites, but there can be little doubt that Rinne's idea of a lattice-shrinkage, the reaction-velocity of which is, at least for moderate temperatures, lower than the velocity of dehydration under the usual experimental conditions, offers the correct explanation. The structure remains fundamentally the same during both dehydration and lattice-shrinkage, but this does not exclude quite appreciable continuous migrations of the various atoms in so far as they have variable parameters.

Apart from the lattice-shrinkage, such a continuous dehydration is simply an instance of the possible but uncommon case where a hydrate and the corresponding anhydrous salt form mixed crystals.[1] That the water molecules probably have definite positions in the unit cell is shown by W. H. Taylor's X-ray study (1930) of analcime and dehydrated analcime.

While such a theory probably represents all the behaviour in some cases, there are others (e. g. natrolite, scolecite, and mesolite) in which the most recent work, mainly that of A. Cavinato (1927), has

[1] An instance of a hydrate which forms mixed crystals with a lower hydrate was first noted by H. Buxhoevden and G. Tammann (1897) in magnesium platinocyanide ($MgPtCy_4.7-6H_2O$), and its dehydration studied by G. Tammann (1897). G. Wyrouboff (1900) added two examples, sodium ammonium ferri- and alumino-oxalates, $Na_3Am_3Fe_2(C_2O_4)_6.7-5H_2O$ and $Na_3Am_3Al_2(C_2O_4)_6.7-5H_2O$. E. Löwenstein (1909) added further instances, oxalates of some of the rare-earths, a basic oxalate of zirconium, and strychnine sulphate ($6-0H_2O$). This list includes, in strychnine sulphate and the rare-earth oxalates, definite cases where the hydrate is miscible with the anhydrous salt. The basic zirconium oxalate (a definite crystalline compound) is especially remarkable because its crystals, when immersed in water or suspended in water vapour at a sufficient pressure, can swell to some eight times their original bulk without losing their sharpness of outline or birefringence. In this they resemble the crystallized proteins studied by A. F. W. Schimper (1881). These 'swelling' crystals are deserving of much more detailed study, and perhaps constitute an extreme (and readily reversible) case of the 'Gitterreaktion' or lattice-shrinkage.

indicated that there is a discontinuity. Here it is probable that we have relations corresponding to an interrupted series of mixed crystals. Up to a certain point the dehydration proceeds continuously, a mixed crystal of hydrate and anhydrous salt (or lower hydrate) forming. But when a certain temperature is reached, this mixed crystal becomes unstable with respect to another, in which the anion has practically the same atomic positions, but the positions of the kations and the number and positions of the water molecules have altered, often considerably. Water is lost suddenly, there is a sharp break in the dehydration curve and optical properties, and the crystal-system may change. But because of the bonded structure of the anion, its constituent atoms may shift their positions slightly to fit in with a different symmetry, without the crystal disintegrating; α- and β-quartz exemplify such a change. This new mineral then exhibits the same continuous dehydration as the original material, proceeding to form mixed crystals with its anhydrous salt. It is also possible that a transformation might occur without change in the water content, and this may yet be met with in the less-studied zeolites.

While this theory seems to the author to be the only one that satisfactorily outlines all the relations of the zeolites and their dehydration products, other views have been and are held. The property of continuous dehydration and reabsorption, discovered and further studied by A. Damour (1857, 1858) was at first merely regarded as a curious fact and no explanation attempted. But when the constancy of the vapour-pressure of hydrated salts had been demonstrated, and the phase rule came to be generally applied in physico-chemical studies, the peculiar position of the zeolites was realized.

The continuity of the dehydration was emphasized by the continuity of the concomitant optical changes, and E. Mallard (1882) compared the zeolites to a sponge which merely imbibed water in its pores. This view was also adopted by G. Friedel (1896) when he found that dehydrated zeolites will absorb other vapours in place of water—carbon dioxide, hydrogen, alcohol, hydrogen sulphide, silicon fluoride, and even air. In various forms it has been adhered to by G. Bodländer (1898), E. Sommerfeldt (1902), C. Doelter (1905), F. Zambonini (1905, 1906, 1908), and others.

Sommerfeldt believed he had proved that analcime was an adsorption product and not a true hydrate or mixed crystal when he

found a lower experimental value for the heat of rehydration than he had calculated; but Zambonini (1906) showed that the material had probably rehydrated little or not at all, so that the basis of his argument vanishes. Zambonini himself (1905, 1906) bases his conclusions largely on the fact that the reversibility is not perfect, time and temperature of dehydration affecting it. This effect is probably due simply to the lattice-shrinkage. The contraction on dehydration had already been noted for analcime by G. Friedel (1896). The possibility of a dehydrated zeolite absorbing more water than it set out with, when initial conditions are restored, is simply due to adsorption on the walls of the fissures invariably present in large numbers when dehydration has been carried to any extent. These eventually fill with liquid water.[1]

Following on his discovery of the continuous dehydration of $MgPtCy_4.7\text{–}6H_2O$, G. Tammann (1897) formulated the view above adopted, that zeolites are essentially mixed crystals of hydrate and anhydrous salt. He pointed out a distinction between the behaviour of zeolites and of silica gels, to which many observers have compared them. The former show irreversibility only after considerable dehydration, whereas the gels only show reversibility at small degrees of hydration. F. Rinne (1899, 1913, 1920) agreed with Tammann, and E. Löwenstein (1909) adduced further evidence for this view.

Löwenstein pointed out that if a percentage-of-water : vapour-pressure curve is drawn for any temperature for one of the crystallized hydrates of zeolitic behaviour (zeolites, oxalates of the rare-earths, &c.) the curve is concave to the pressure axis (d^2p/dc^2 is positive), whereas for the colloids such as silica gel, clays, or the ferrocyanides of zinc and copper, it is convex (d^2p/dc^2 is negative). More strictly, the curve is S-shaped, and this criterion applies to the more advanced stages of the dehydration. $MgPtCy_4.7\text{–}6H_2O$ forms an apparent exception, the curve being convex to the pressure axis, but this is probably because only the first half of the S, so to speak, can be

[1] Thus if 2 grams natrolite (volume 1 c.c. approx.) have absorbed 3 % extra water, this corresponds to fissures of volume 0·06 c.c. To cause opacity, the fissures must have been about $100\mu\mu$ wide at least. (An absorption of any appreciable amount of extra water will not occur unless dehydration has been carried well beyond the point at which it produces opacity.) If this is taken as the width of the fissures, they will divide the crystal into fragments of about 0·1 mm. size; study shows that fissures of such number and dimensions may quite reasonably be assumed.

observed, breakdown to the pentahydrate preventing observation of the point of inflexion.

F. Grandjean (1910) extended the list of substances which dehydrated zeolites will absorb to include iodine, mercury, sulphur, and cinnabar, and noted that the products are often pleochroic, which led him to adopt the solid solution theory. It is not every vapour or liquid, however, that can be absorbed. Thus O. Weigel and E. Steinhoff (1925) found that while chabazite will absorb ethyl and methyl alcohols and formic acid, it does not absorb ether, benzene, or acetone, the molecules of which are probably too large to pass through the meshes of the anionic net. Oils, too, merely fill all crevices and fissures, but are not taken up into the crystal-structure. Further, some vapours and gases are much more readily absorbed than others; thus R. Seeliger (1921) found that nitric oxide and ammonia were absorbed far more readily than other gases of comparable boiling-points. R. Nacken and W. Wolff (1921) have also studied the absorption of gases by dehydrated chabazite.

O. Weigel (1924) has put forward a formula enabling him to calculate the absorption to be expected for any molecule which will pass the meshes of the silicate net, but it requires much more testing; and it may be remarked that although he develops it on the assumption that the water and other molecules have not definite positions in the crystal-structure, this assumption is not strictly necessary. The fact that other vapours than water can be absorbed is, of course, simply due to the residual affinity of the anhydrous structure; if the latter has undergone shrinkage, this largely satisfies the affinities within the structure itself, and neither other vapours nor water can be absorbed. The absorption will also be affected by the polarity of the molecules offered for absorption, the more polar ones, with greater free affinity, being more absorbed, provided, of course, that they can pass the meshes of the silicate net.

An entirely different view of the condition of the water in zeolites has been put forward by A. Beutell and his co-workers (A. Beutell and K. Blaschke, 1915; G. Stoklossa, 1918; A. Beutell, 1921). These observers consider that the continuous dehydration curve does not correspond to equilibria, but is influenced by 'cohesion' effects. Rehydration curves are not so invalidated, and by a study of these, it is concluded that the zeolites are simply hydrates of the normal type, the rehydration proceeding step-wise. For each species a large number of hydrates are established. Other workers (O. Weigel,

1919, 1921; K. H. Scheumann, 1921) have shown that it is these rehydration curves that do not correspond to true equilibria, and have succeeded in attaining the equilibrium curve from both sides (within the reversible range). The rehydration curves of false equilibrium are not, however, without their significance, for they show a marked fall in the velocity of rehydration at points corresponding to integral numbers of water molecules, probably indicating a slightly enhanced stability of such compositions due to their more perfect homogeneity.

The other most characteristic property, distinguishing zeolites from most other minerals and most other hydrates, is their capacity for base-exchange. Like the dehydration phenomena, this property is consequent on their peculiar structure, the strong, stable anion with its open build permitting a mobility of the kations, which is demonstrated by their high electrical conductivity as compared with most other solid salts, as well as by the base-exchange.

The electrical conductivity of a number of zeolites has been measured by O. Weigel (1923). He interprets his observations as indicating that the kations play no part in the conduction, which he attributes to the water. But the matter requires much further investigation, for his values are not of the same order as those of Günther-Schulze (1914), who confirmed his measurement of the electrical conductivity of natrolite by measurements of the velocity of base-exchange.

Weigel found that the resistance is greatly increased by slight dehydration, and bases his conclusion largely on this. Günther-Schulze found the same effect for permutite, an artificial product closely allied to the zeolites. But he demonstrated conclusively that in this case the kations are responsible for the conduction, since on electrolysis of dry sodium-permutite between copper electrodes, a layer of blue copper-permutite was formed at the anode. The present author has attempted to repeat this experiment with zeolites (heulandite, natrolite) but without success, owing probably to the much lower conductivity of the zeolites.

The increase of resistance on slight dehydration is probably due to a decreased mobility of the kations, the attraction of the anionic complex being increased by the removal of the highly polar water. And the increase in the resistance with time, when the zeolite is electrolysed between dry electrodes, is probably due to the formation of a thin layer of electrolysis products at each electrode, imposing

a high film resistance. That removal of the water does decrease the mobility of the kations is shown by the observation of A. Beutell and K. Blaschke (1915), that after dehydration to the irreversible stage, zeolites almost lose the property of base-exchange. Lattice-shrinkage may also account for part of the loss.

The phenomenon of base-exchange was first discovered by J. T. Way (1850, 1852, 1854) as a property of soils. H. Eichhorn (1858) found that it is shared by zeolites, and satisfied himself that when a zeolite is treated with a salt solution, there is simply an interchange of kations in equivalent amounts; the anion remains unabsorbed; and, provided the salt is either neutral or alkaline in reaction, the zeolite is not decomposed, losing neither silica nor alumina.

H. Schneiderhöhn (1915) has summarized and criticized the extensive studies of J. Lemberg (1876, 1877, 1883, 1885) and S. J. Thugutt (1892, 1895) and concludes that they are of little value, since most of the products were amorphous, and it is often quite uncertain how far any of them were homogeneous.

E. Löwenstein (1909) showed that a number of potassium-zeolites had higher vapour-pressures for the same temperature and water-content than had the corresponding natural calcium salts; and that on re-converting the potassium salts to the calcium salts, the original vapour-pressures were restored.

I. Zoch (1915) made a thorough study of the base-exchange of stilbite, and demonstrated that the reaction is not complete, but leads to a definite equilibrium between the kations involved in the solution and in the crystal. His studies are the first to show definitely that the anion really remains unaffected by the base-exchange, the material retaining its crystalline nature, while the optical properties change in a continuous manner, the original optical properties returning in all respects when the original composition is restored. This important point the work of F. W. Clarke and G. Steiger (1899, 1900, 1902, 1905) lacks, though they showed many of their products to be homogeneous and crystalline. They studied the action of fused silver and thallium nitrates and of dry ammonium chloride, and obtained many interesting products, but an optical study of these silver-, thallium-, and ammonium-zeolites is very desirable. That ferrous and silver salts will partake in base-exchange with zeolites was shown by K. Dalmer (1878) and A. H. Church (1899) respectively.

The action of solutions of acid-reacting salts was studied by H. Kappen and B. Fischer (1928), who found that $FeCl_3$, $AlCl_3$, and $ZnCl_2$ give no base-exchange, their activity leading to complete decomposition of the zeolite. Ferrous and copper salts, on the other hand, gave a true base-exchange, at least with the less acid-sensitive zeolites. These workers were mainly interested in the exchange-acidity, that is the acidity, titratable by alkali, communicated to a neutral salt solution when it is digested with a zeolite that has been treated with acid or an acid-reacting salt. This phenomenon, discovered by G. Daikuhara (1914), has not yet been properly explained. At first sight, one would imagine hydrogen is participating in the base-exchange and giving a hydrogen-zeolite, which reacts with the neutral salt solution with liberation of free acid. But Daikuhara showed that the salt solution after digestion contains alumina; and Kappen and Fischer found the amount of the latter such that its precipitation accounts for almost or quite the whole of the alkali used in titration. Moreover, analyses by Kappen and Fischer of zeolites before and after acid-treatment show a considerable loss of alumina, but curiously enough, only a small loss of alkalis or alkaline earths when small quantities of dilute acid are used.

With stronger acid,[1] the alumina and bases are totally removed, and a silica gel remains. F. Rinne (1896, 1897, 1902) found that with certain of the more siliceous zeolites (heulandite, stilbite, brewsterite, harmotome, and chabazite) this silica remains coherent and has distinct birefringence, and quite definite optical properties which remain even after ignition. G. Tschermak and his pupils (1903, 1905, 1906, 1908, 1909, 1912) also studied these silica gels, and found that when desiccated at the ordinary temperature, there is a fairly sharp break in the velocity of dehydration. They analysed the material at this point, and took it to represent the particular silicic acid of the zeolite studied. Their results were adversely criticized, with some justice, by O. Mügge (1908) and J. van Bemmelen (1908), and especially by M. Theile (1913). It is, however, probable that they are not without significance in those cases where the silica gel has definite optical properties.

If all the alumina and kations are eliminated, the product will not be coherent unless the Si/Al ratio is high enough. A simple consideration shows that if the ratio is 1 or less, each silicon will be

[1] Strong sulphuric acid, however, only effects a partial dehydration, without decomposition, at least in many cases (F. Rinne, 1896, 1897).

isolated, and the gel cannot be coherent—indeed a sol rather than a gel is likely to be formed. With a Si/Al ratio of 3 or more, on the other hand, the elimination of the alumina will leave a network of silicon and oxygen, which is likely to be sufficiently rigid to retain definite crystalline and optical characters. And it is precisely the zeolites with this ratio which yield such stable skeletons.

While there is no evidence for the existence of hydrogen-zeolites, the free acids may be prepared in one series which in some respects is related to the zeolites. The clays[1] are also aluminosilicates, and they exhibit the phenomena of base-exchange in an even more striking degree than do the zeolites. On the whole, very little is known about them, but they appear to be of a micaceous structure, and are perhaps based on infinite two-dimensional anions. In the property in which they are most comparable to the zeolites—the base-exchange—they show two important differences, the capacity to form free acids, and the ability to take up large kations, such as the methylene blue ion, a property which the zeolites lack. Genetically, they are derived from the breakdown under weathering of felspars, and perhaps also of micas, whereas the zeolites form one of the last deposits from magmatic solutions. The dehydration of the clays has been less studied. E. Löwenstein (1909) studied some of the clay-minerals, and came to the conclusion that they contain no water of zeolitic behaviour, but only adsorbed water and firmly combined water. The latter is presumably present as hydroxyl groups, and constitutes the acidic water of these acids. Löwenstein's conclusions, however, have not been accepted generally. Practically no study of the soil-clays in this respect has been made.

More closely related to the zeolites are the ultramarines, the permutites, and the artificial 'zeolites' first prepared by J. T. Way (1850, 1852). The ultramarines, including not only the wide group of artificial products, but also the natural minerals lazurite, nosean,

[1] Mineralogists in the past have tended to confine the clays to a group composed of silica, alumina, and water only, abandoning the study of the wider group of soil-clays to agriculturalists. Recent developments (see, for example, S. B. Hendricks and W. H. Fry (1930); C. E. Marshall (1930)) have shown that the soil-clays are mixtures containing definite salts of isolable acids, and that the acids are probably, in part at least, to be identified with the clay-minerals. Collaboration of mineralogists and colloid chemists in this field is particularly desirable, for there can be little doubt that the clays with their ready base-exchange play an appreciable part in maintaining conditions favourable to plant-life in the portion of the earth's crust of greatest importance to mankind —the soil.

haüyne, and sodalite, have a structure very similar to that of the zeolites; but in place of mobile water, they have mobile anions (Cl',SO_4'',S_3'', &c.) and the concomitant kations (Na',K',Ag',Ca'',Ba'', &c.). They show a ready exchange of both anions and kations (F. M. Jaeger, H. G. K. Westerbrink, and F. A. van Melle, 1927; F. M. Jaeger and F. A. van Melle, 1927, 1929; F. M. Jaeger, 1929).

The permutites, discovered by R. Gans (1905, 1906) have been very widely studied, but with very little result from the mineralogical point of view. Prepared by the fusion of kaolin with sodium carbonate and leaching the product with water, they have similar compositions to the zeolites, having the ratio $Al_2/(Na_2,Ca) = 1$ (whence $O/(Al,Si) = 2$), and a variable Si/Al ratio[1] in the neighbourhood of $1\frac{1}{2}$–2. In base-exchange they resemble the zeolites, except that the velocity of reaction is far greater, in accordance with the greater velocity of kationic diffusion and greater electrical conductivity, as observed by Günther-Schulze (1914). As with the zeolites, and unlike the clays, large ions (e. g. methylene blue, or the tetramethylammonium ion) and hydrogen cannot partake in the exchange. Their dehydration does not appear to have been studied. No crystalline structure has been detected, but the grains are coherent, and appear as a rule very free from fine fissures or pores, though of a coarsely porous structure. For methylene blue only stains a very thin skin on the surface, without penetrating the grains (G. Weigner and K. Müller, 1929). This rather suggests that they are perhaps 'amorphous' zeolites, not devoid of structure, but devoid of symmetrical arrangement, consisting of an infinite tridimensional anion of Al, Si, and O, together with kations and water molecules, precisely like the zeolites, but without the regular arrangement of the Al atoms and kations which gives the latter their crystalline character.

Lastly, the 'artificial zeolites' prepared by J. T. Way (1850, 1852), H. Deville (1862), and B. von Ammon (1862), by the interaction of solutions of sodium aluminate and sodium silicate, sodium aluminate and silica gel, or sodium silicate and alumina or aluminium salts, are also related to the zeolites in many ways. They have been little studied (cf. R. Gans (1906), and F. Singer (1910)), but some work has recently been done by P. S. Burgess and W. T. McGeorge

[1] F. Singer (1910) prepared permutites with Si/Al ratios up to 10, and also replaced Al by B,V,Mn,Fe, and Co, and Si by Ti and Pb, while for Na he substituted K,Am,Mn,Ni,Ca,Cu,Ba, and Ag.

(1927), who rediscovered them, and by O. C. Magistad, (1928, 1929). They also have the ratio O/(Al,Si) = 2, but the Si/Al ratio varies over a much smaller range than in the permutites, for a large variation in the Si/Al ratio for the solution. Their base-exchange relations closely resemble those of the zeolites and permutites. Structurally nothing appears to be known about them. They may perhaps be identical with the permutites, or they may be a colloidal mixture of zeolites. In either case, they will undoubtedly repay further study.

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